

Arsenic distribution and occurrence in ground-water from Coastal Plain aquifers of Maryland

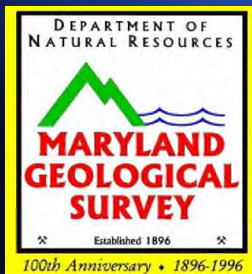
Preliminary Results

David D. Drummond
and

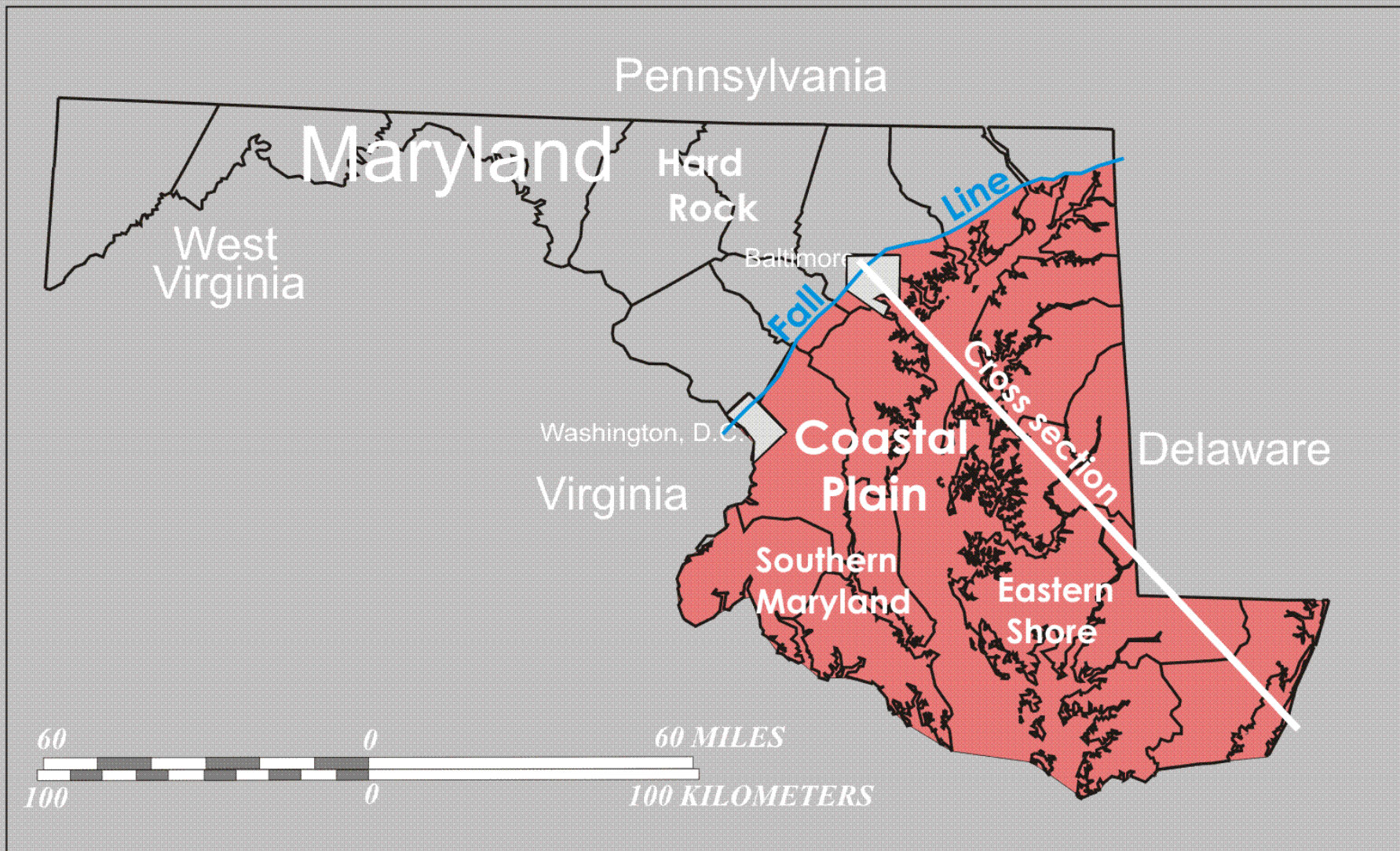
David W. Bolton
Maryland Geological Survey

Funding

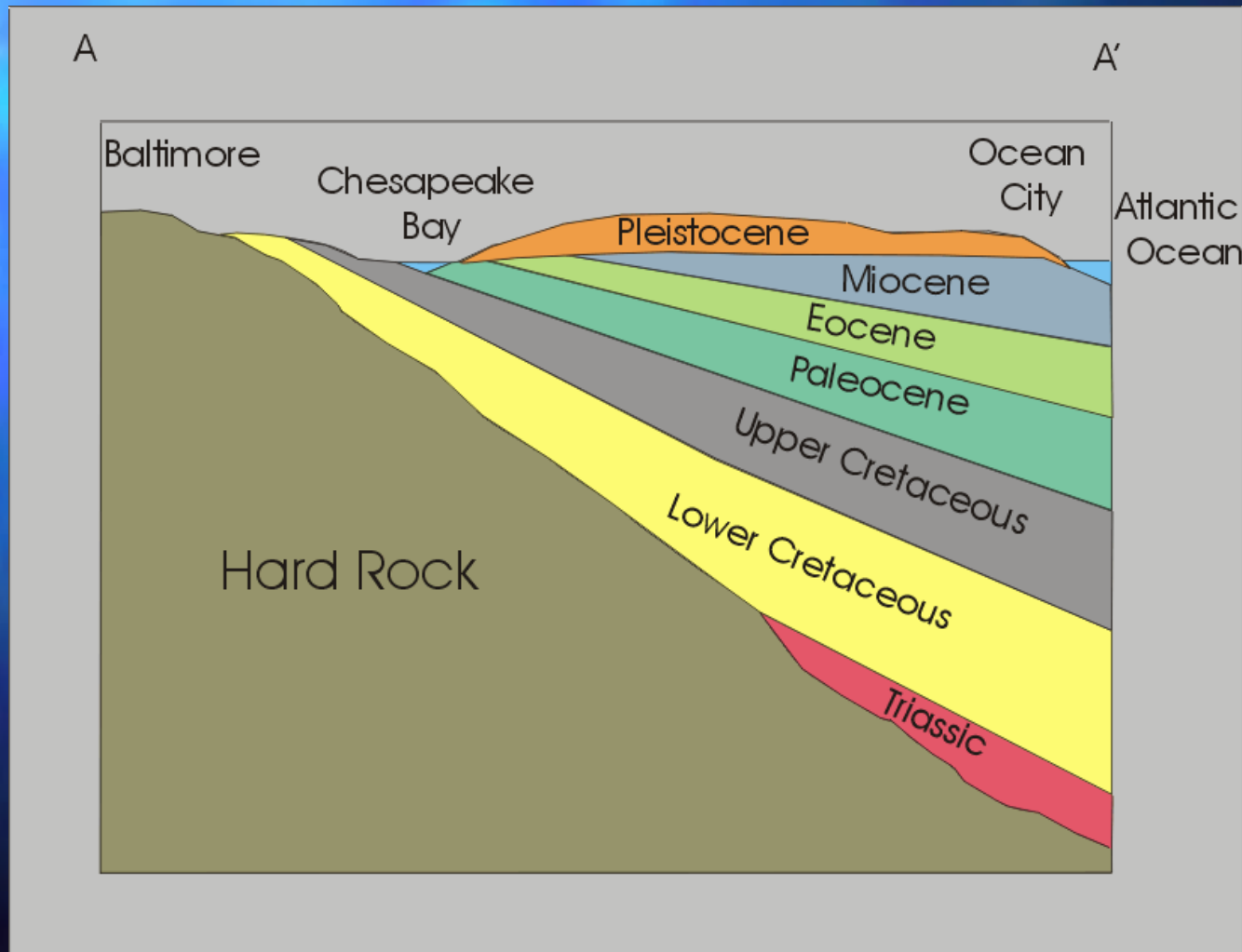
- Maryland Department of Natural Resources
- Maryland Department of the Environment



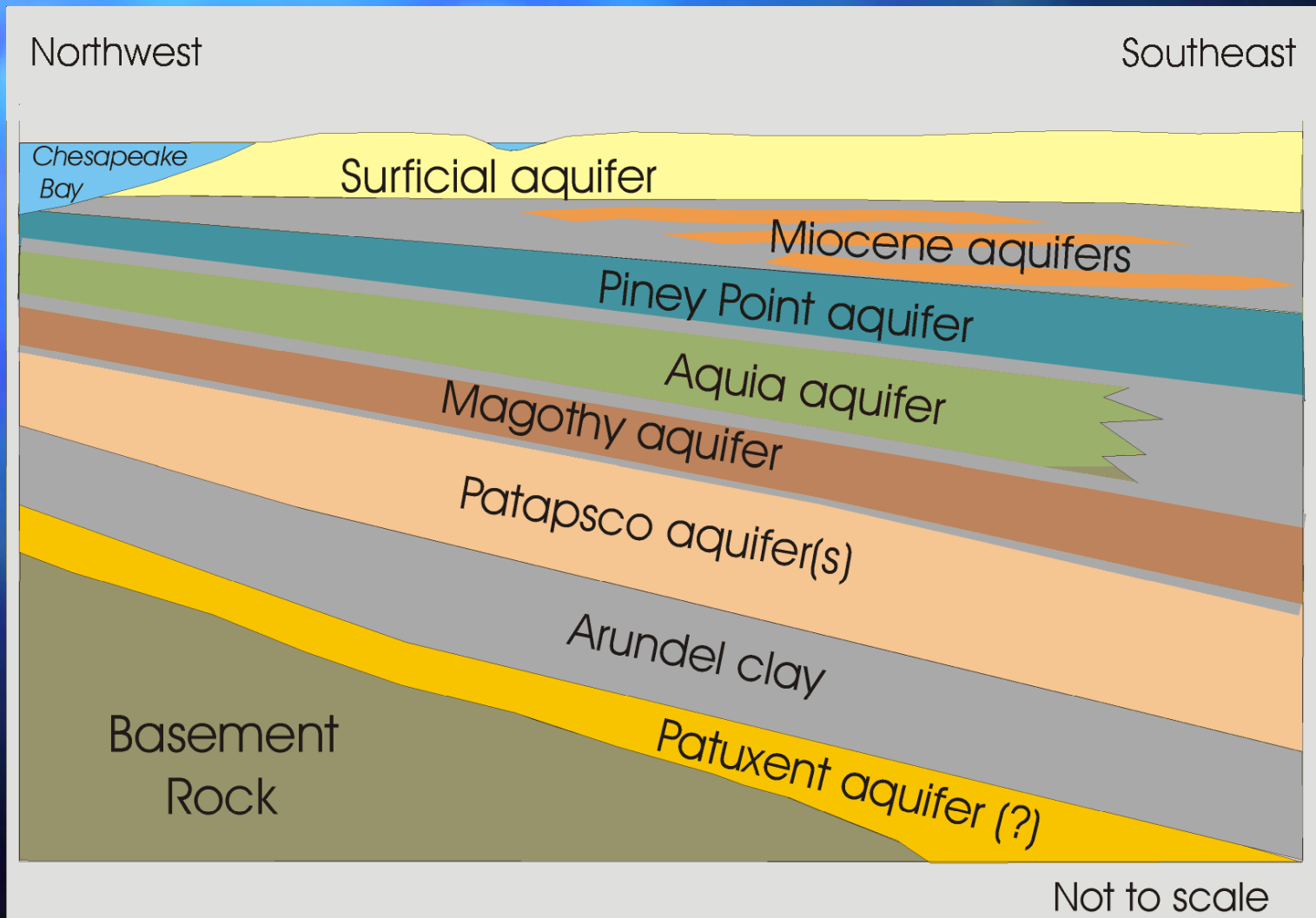
Location of study area



Schematic Cross Section Baltimore to Ocean City

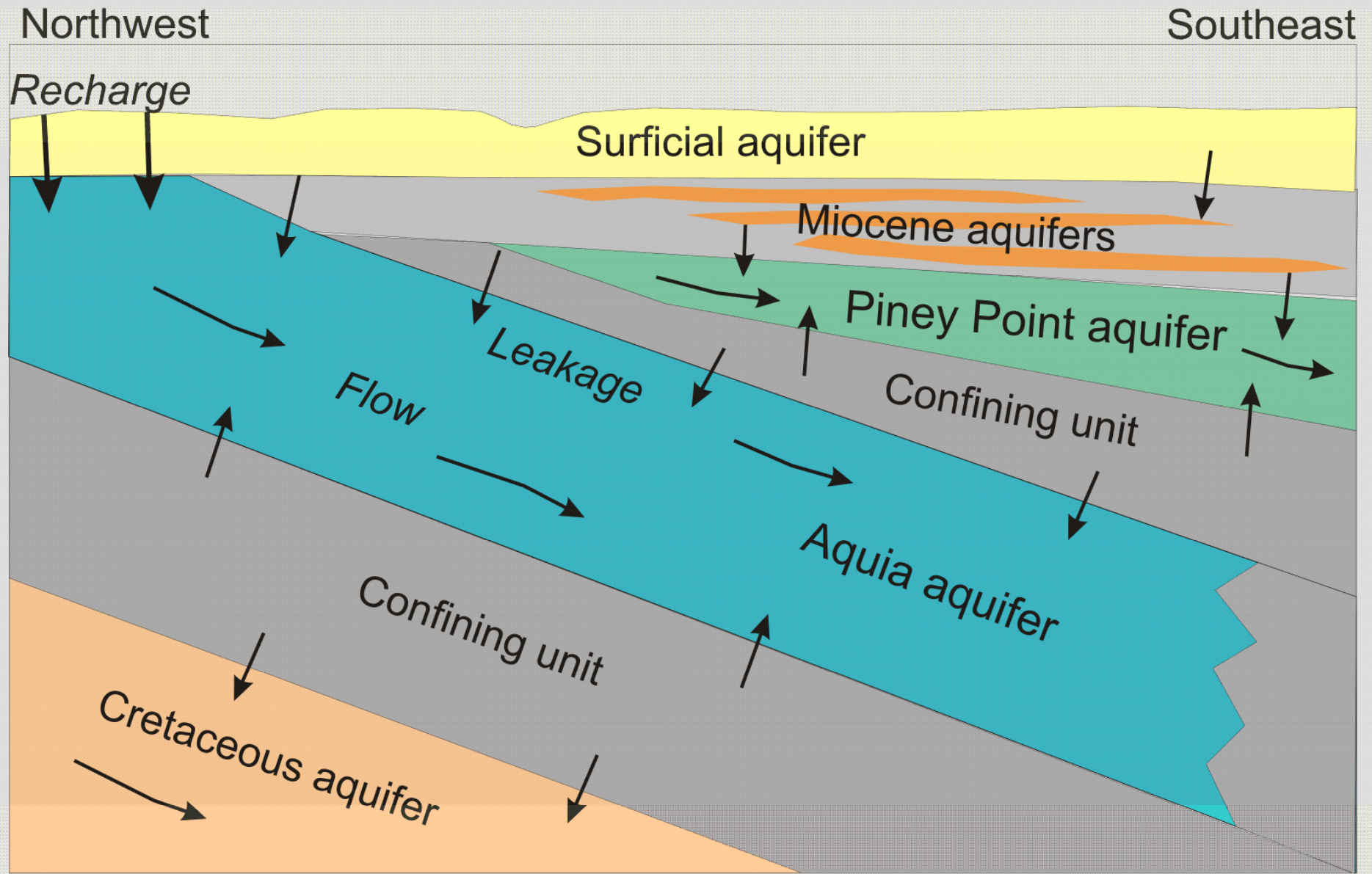


Coastal Plain Aquifers of Maryland





Ground-water flow in the aquifers

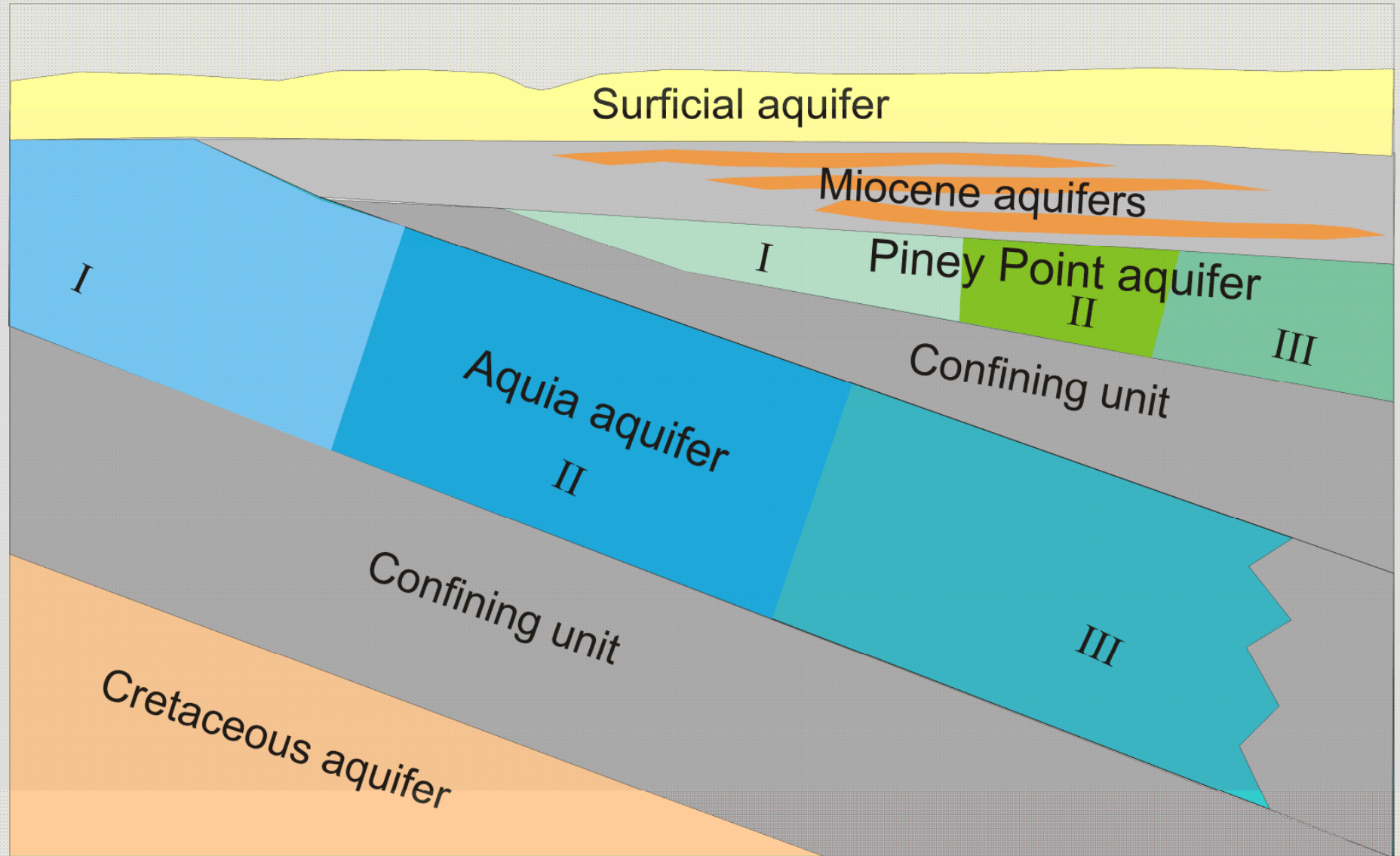


Not to scale

Hydrochemical zones in aquifers

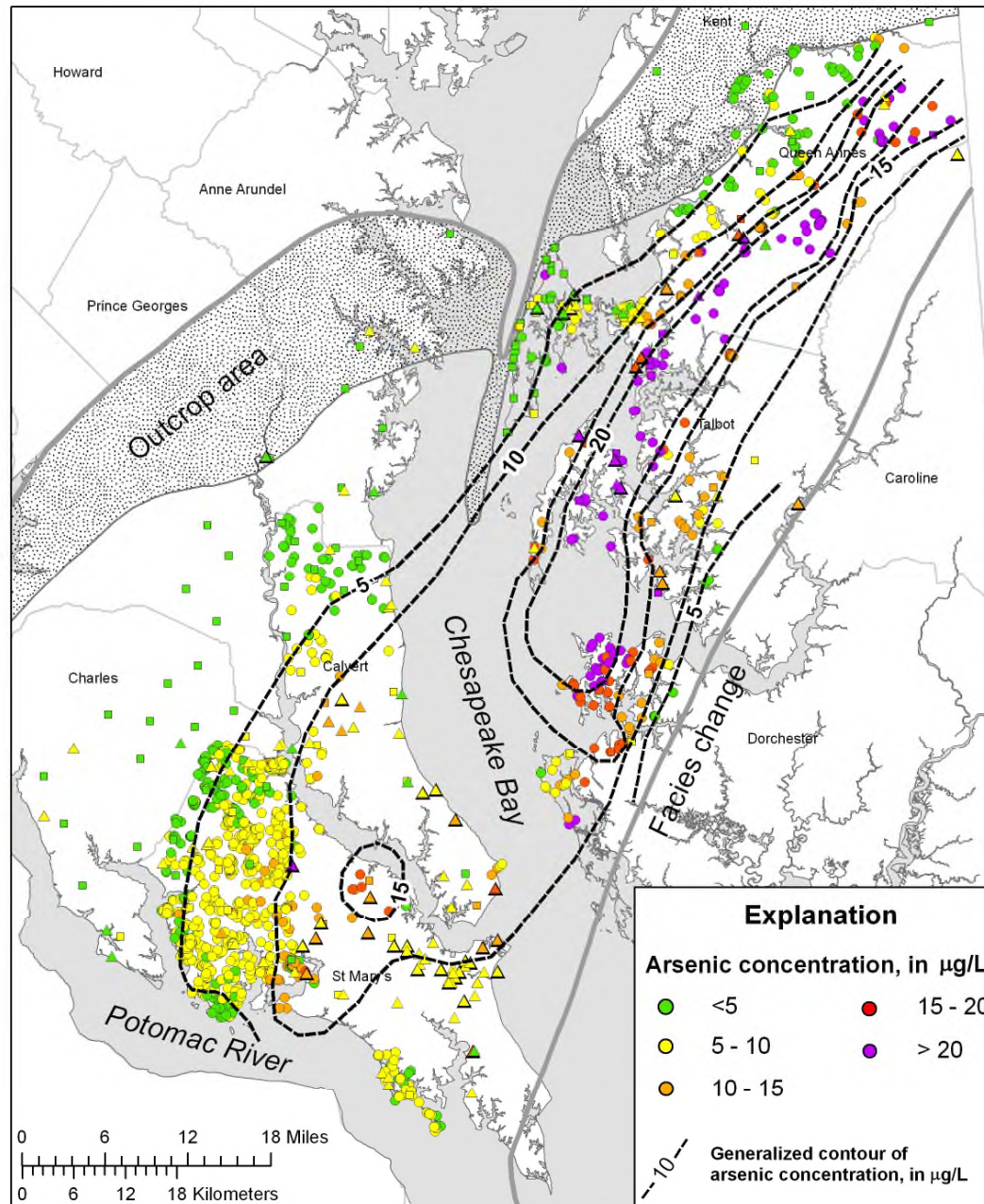
Northwest

Southeast

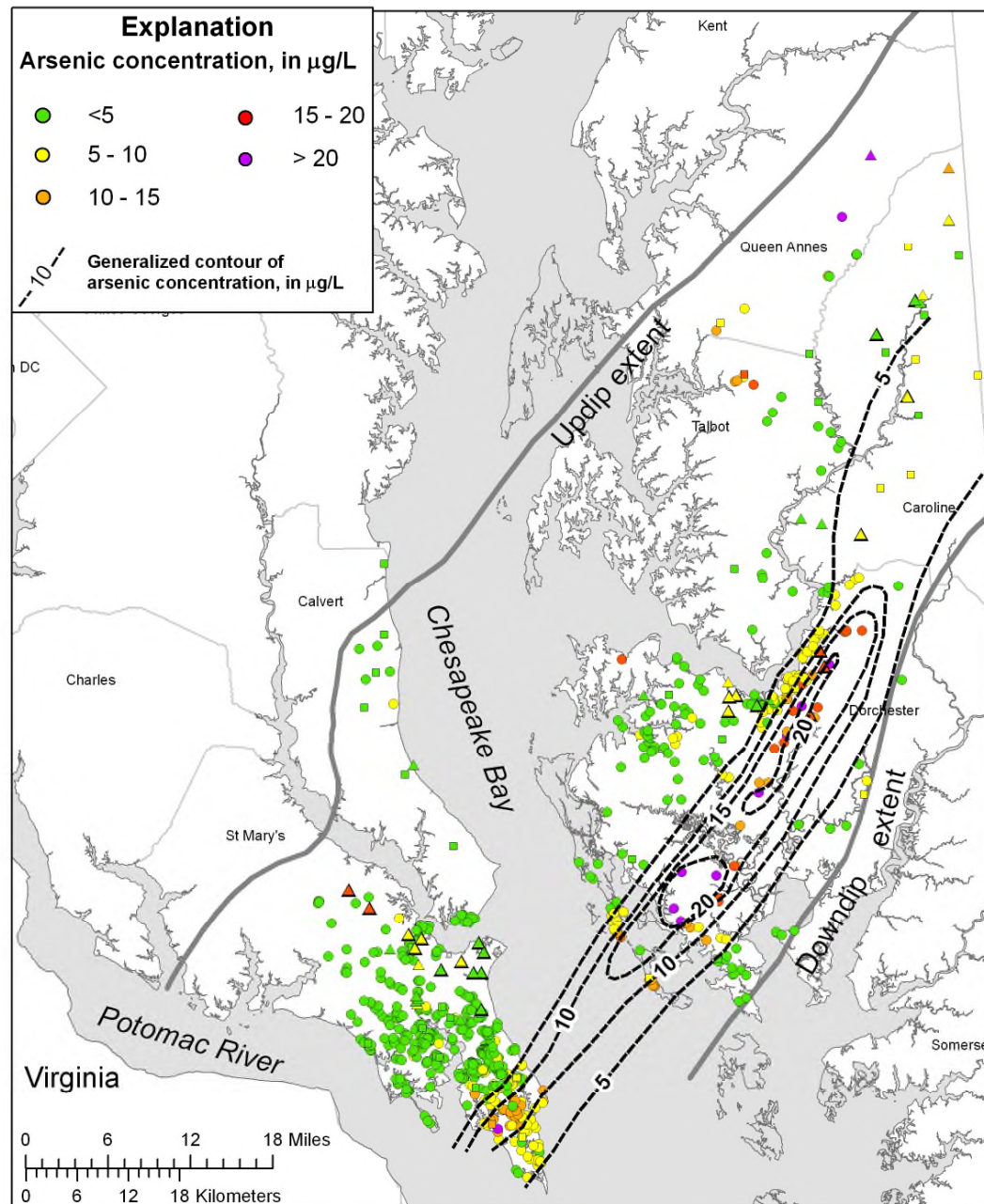


Not to scale

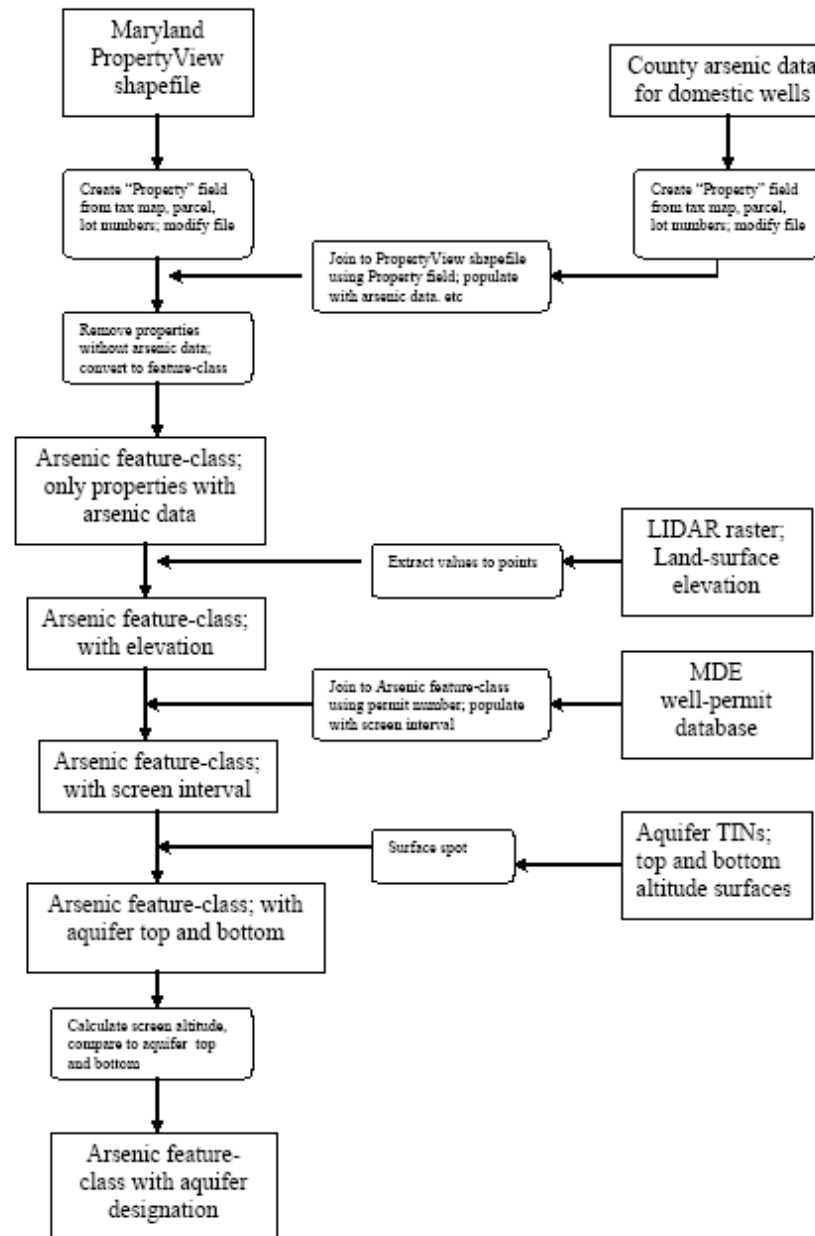
Arsenic concentrations in the Aquia aquifer



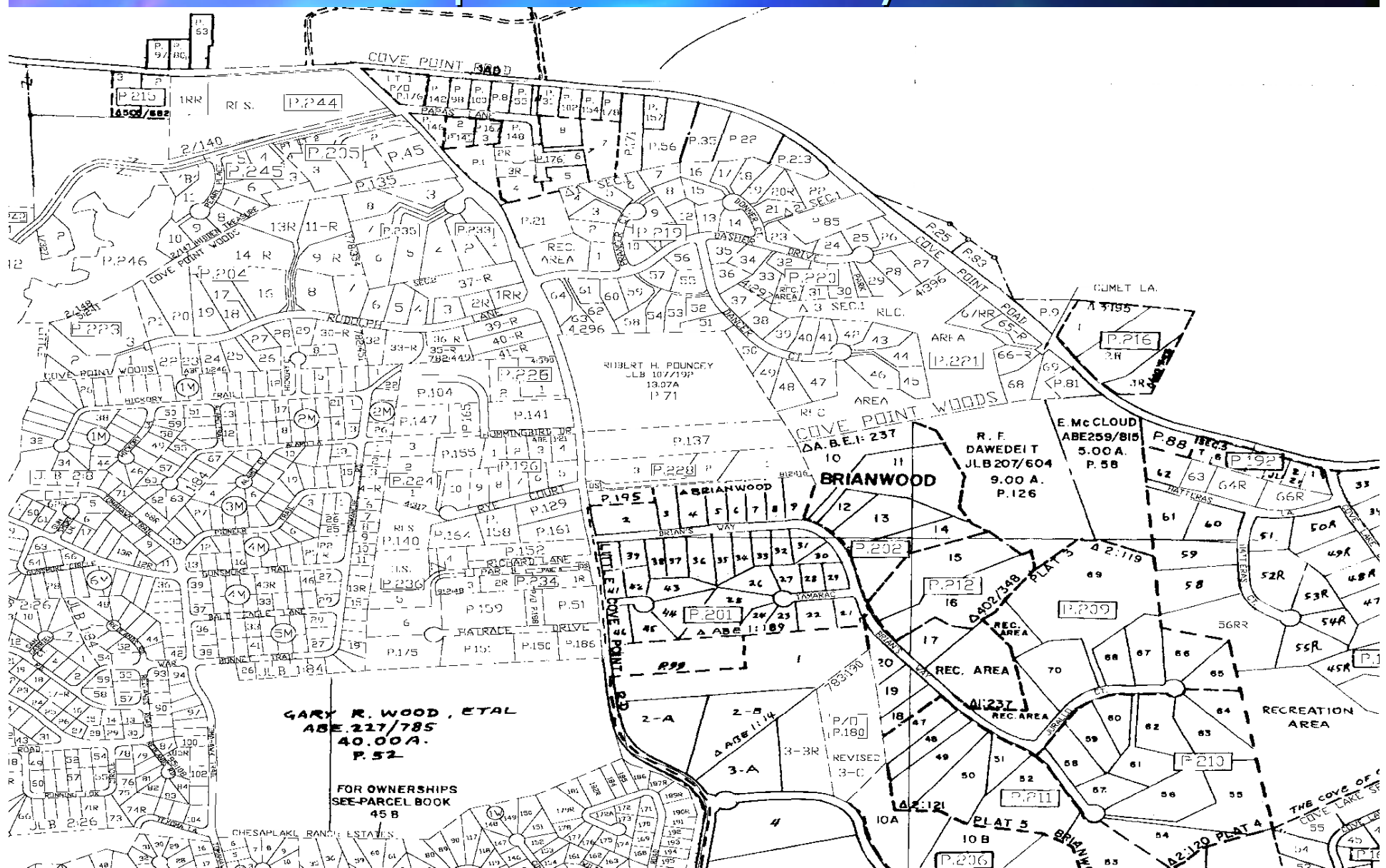
Arsenic concentrations in the Piney Point aquifer



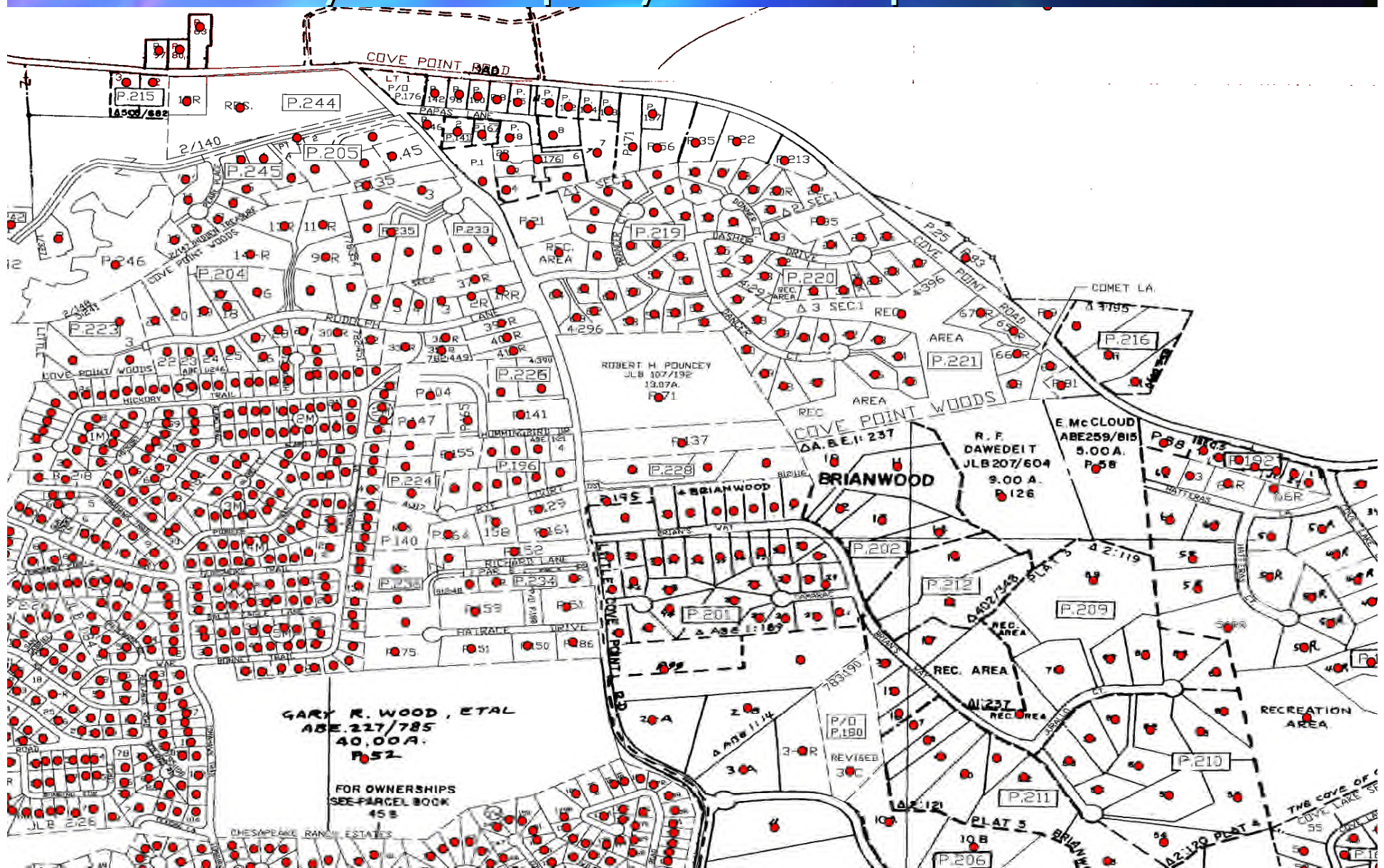
Flowchart to process county arsenic data from domestic wells



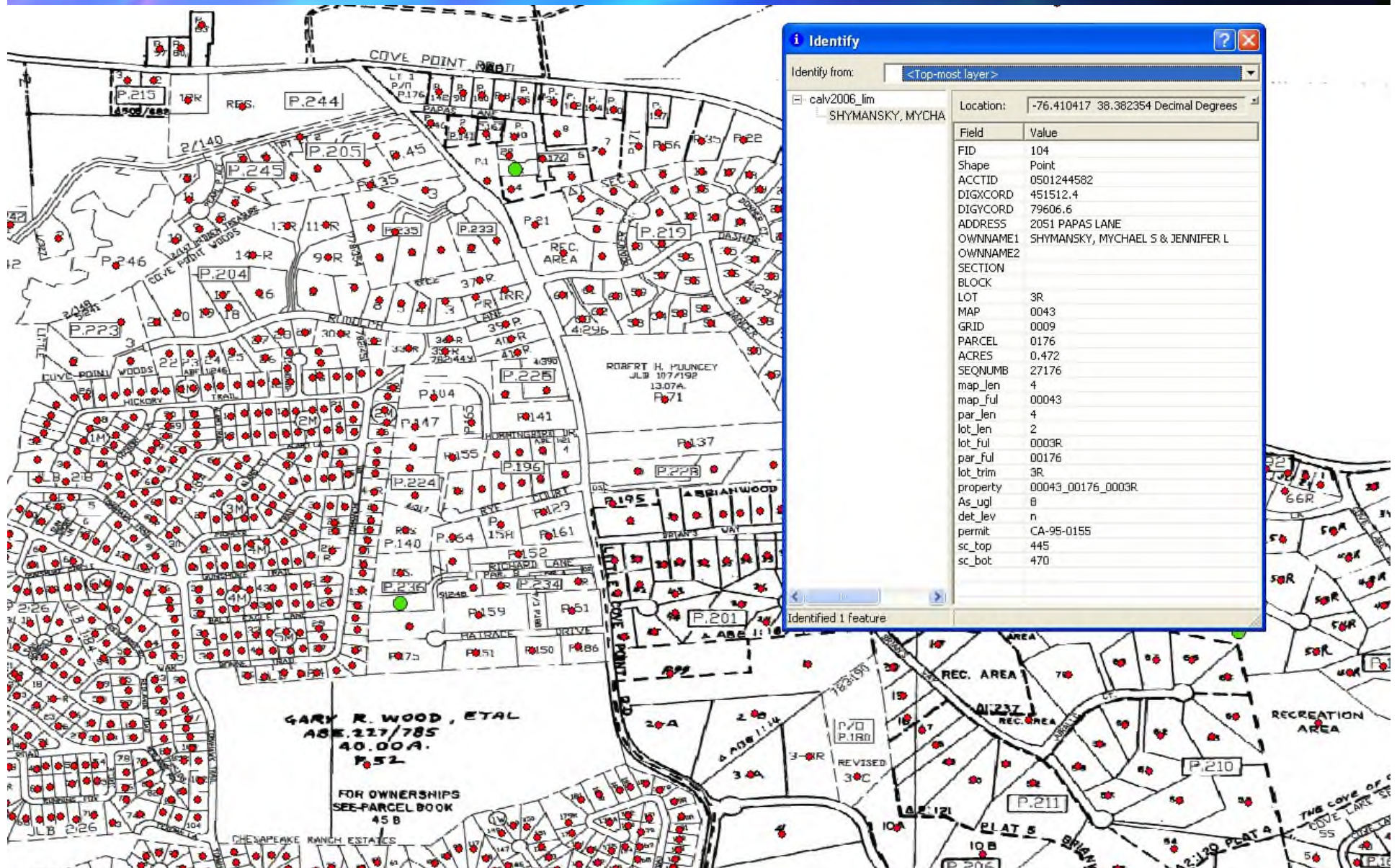
Tax map in Calvert County



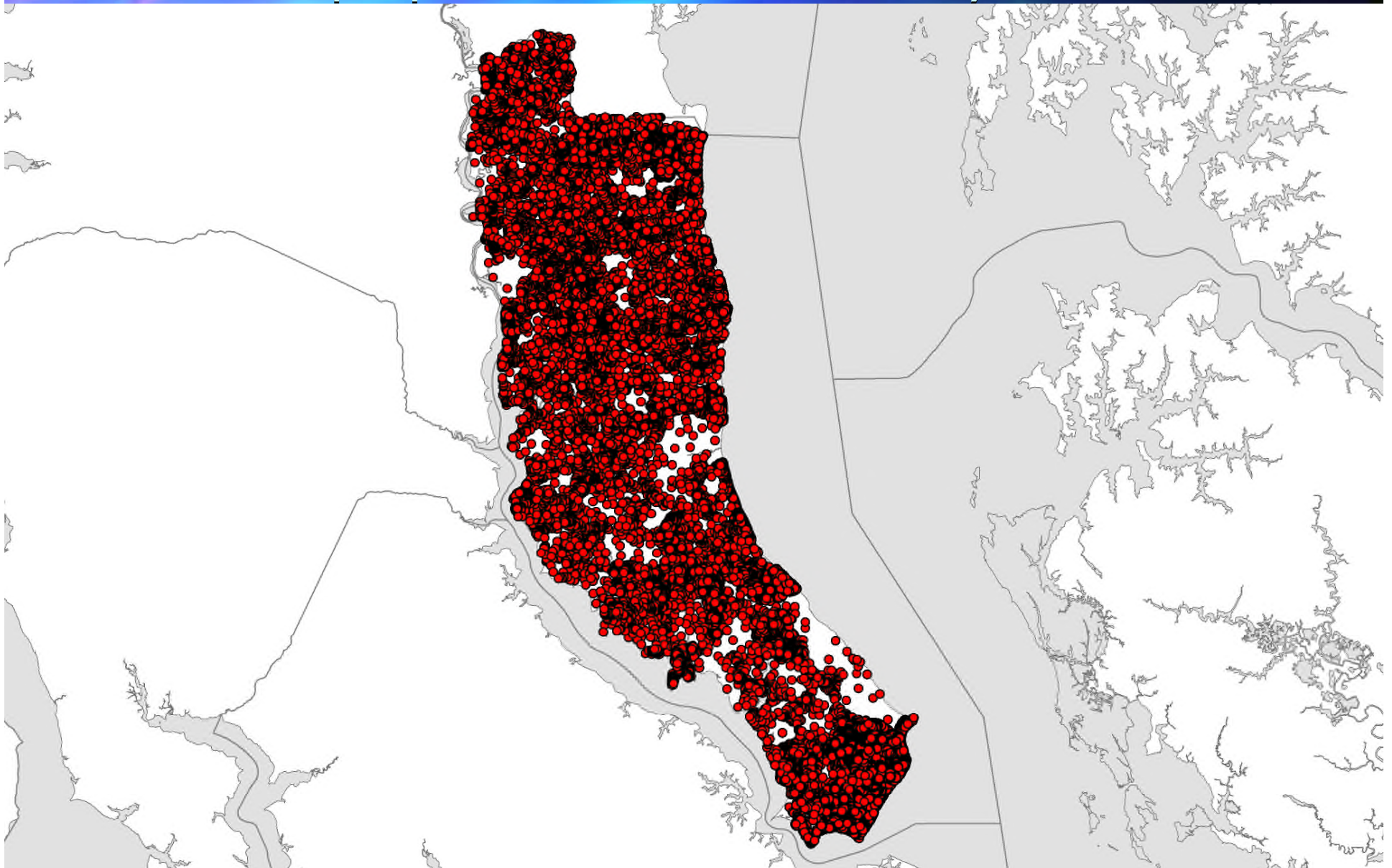
Maryland Property View shapefile



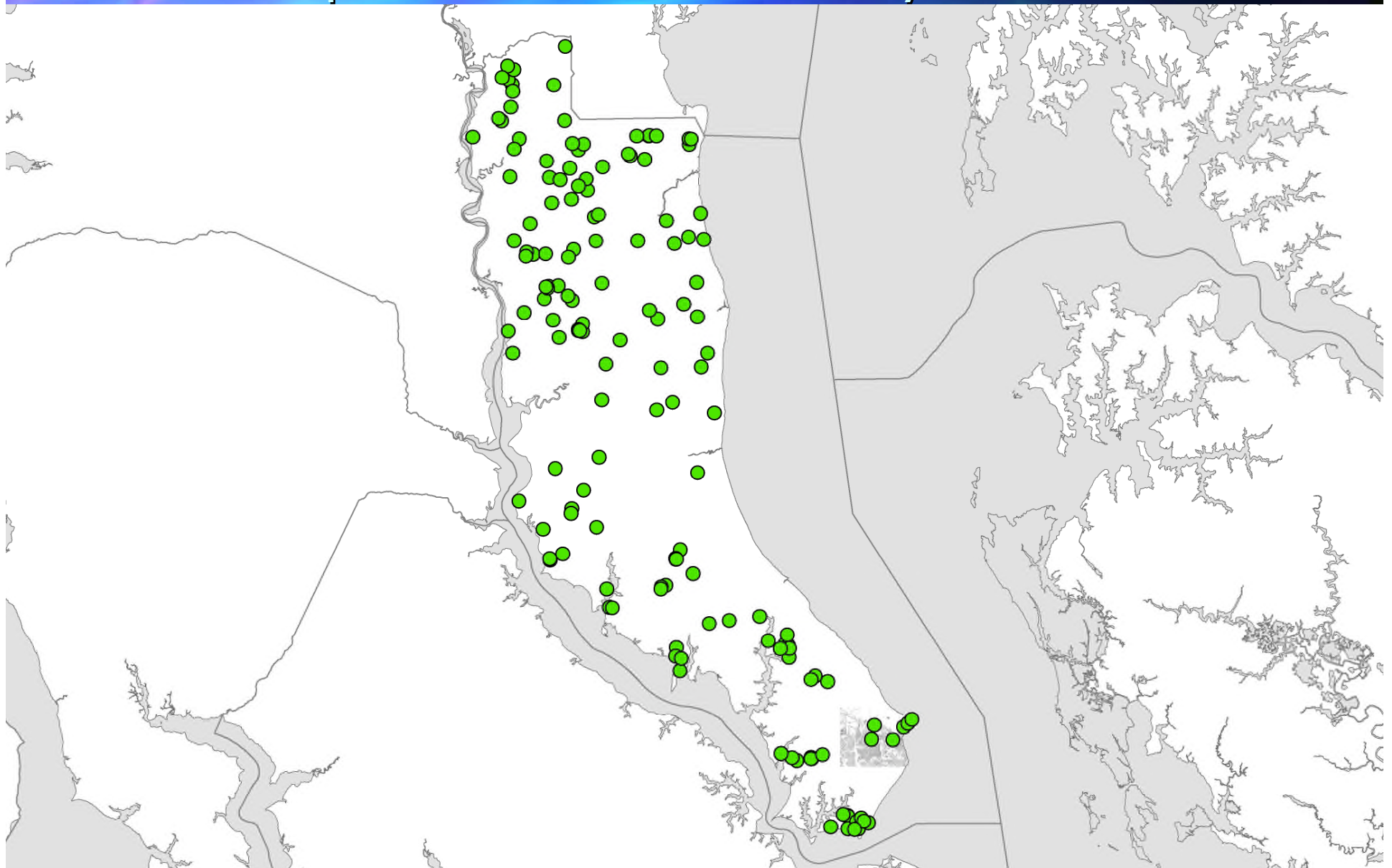
Information available for wells



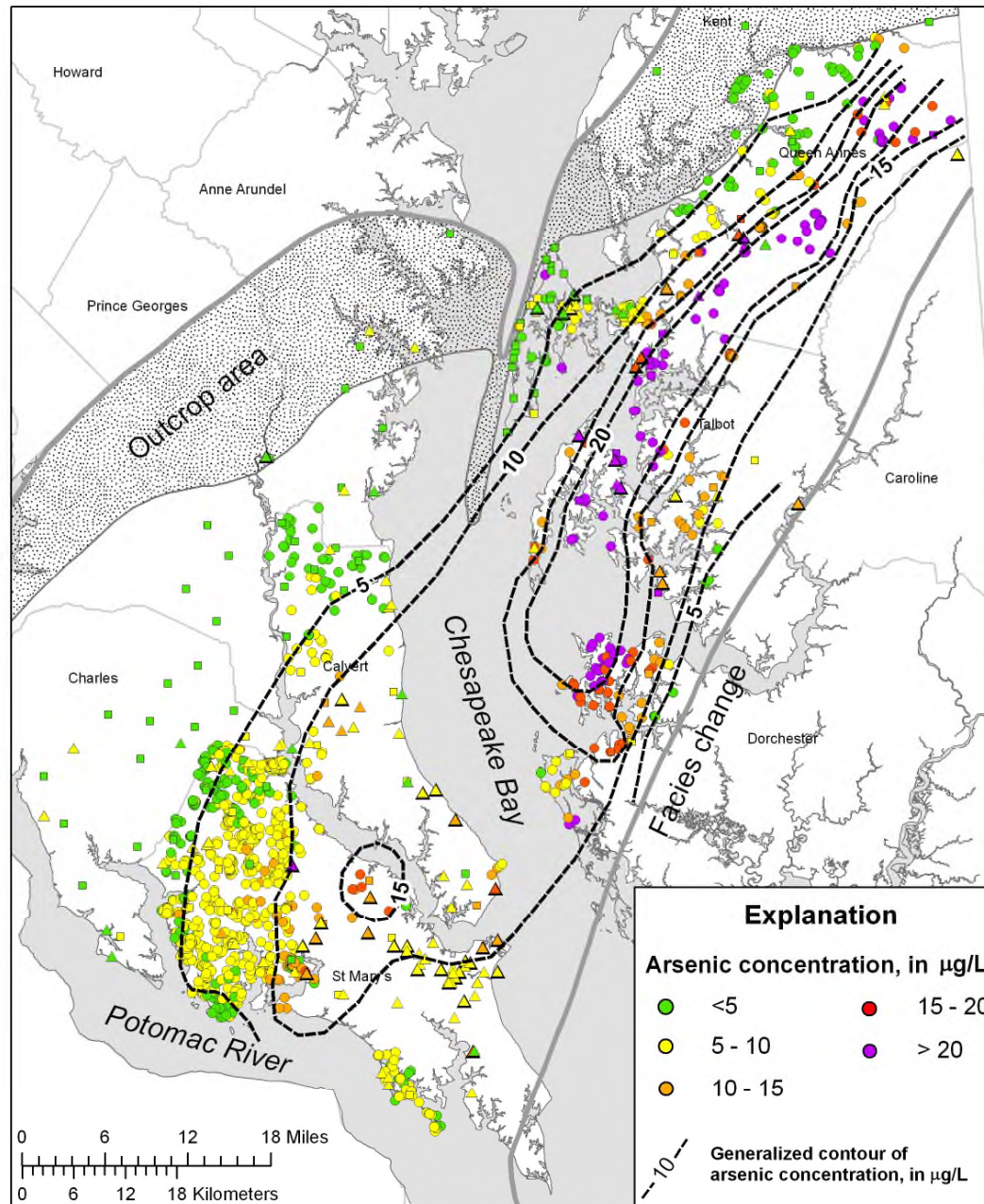
All properties in Calvert County



Properties with arsenic analyses



Arsenic concentrations in the Aquia aquifer

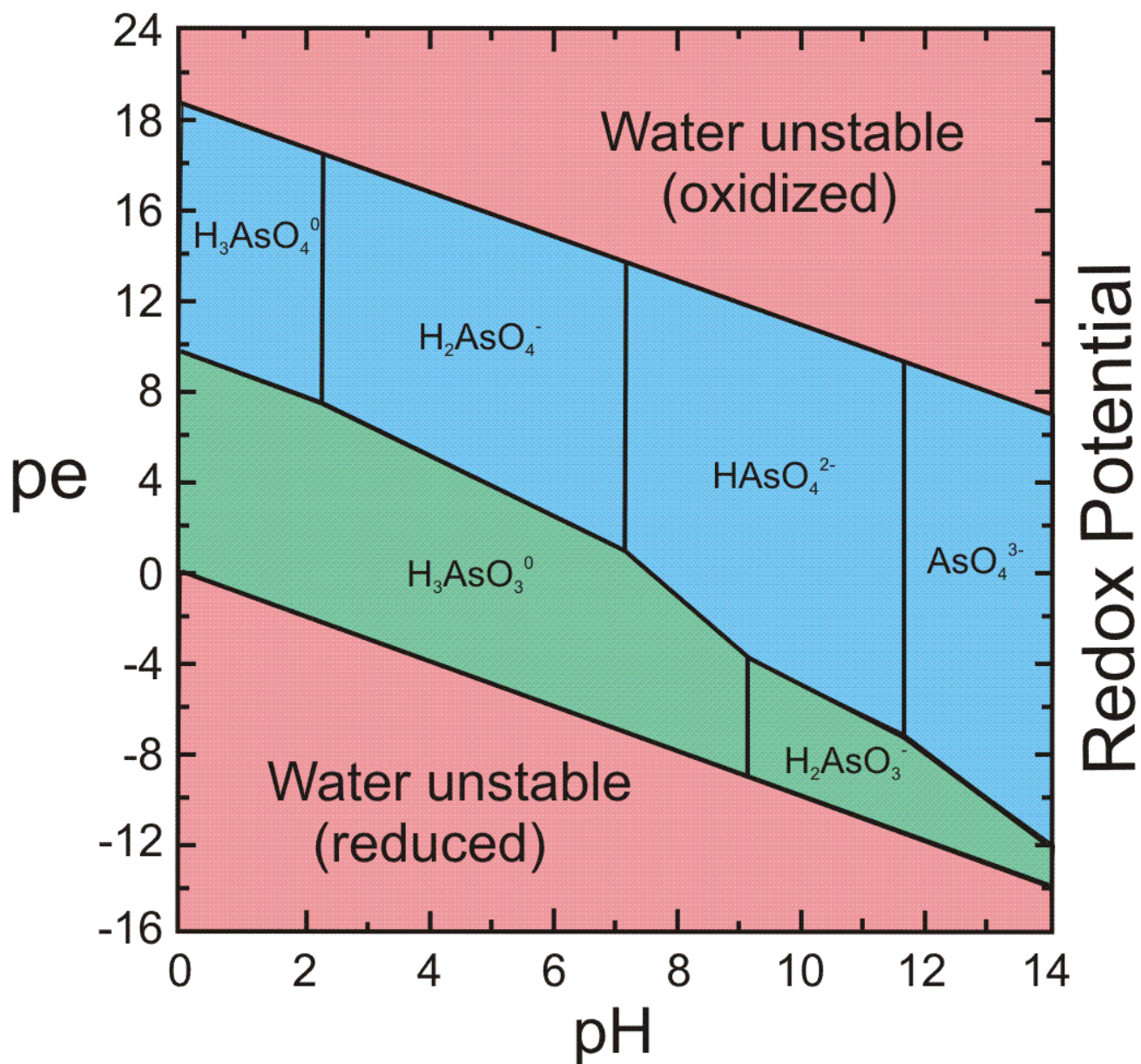


Forms of dissolved arsenic

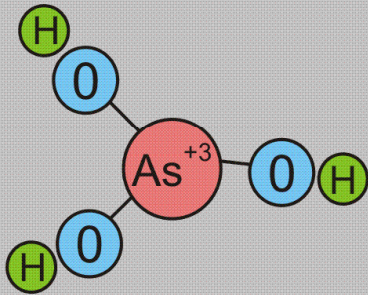
- Arsenate (As^{+5}) (As V)
 - Oxidized form
 - Moderate toxicity
- Arsenite (As^{+3}) (As III)
 - Reduced form
 - Highest toxicity
- Organic arsenic
 - Combined with carbon, oxygen
 - Low toxicity

pe-pH diagram for aqueous arsenic species

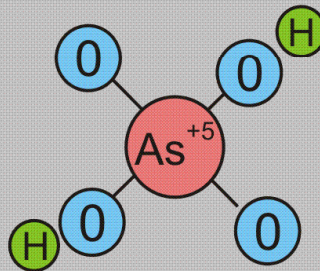
(at 298° K and 1 atmosphere pressure)



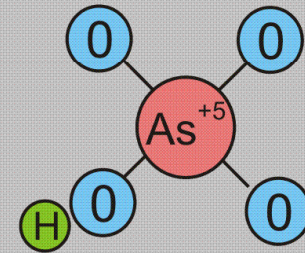
Arsenic complexes



H_3AsO_3^0
Reducing conditions
Neutral
Weakly adsorbed



H_2AsO_4^-
Oxidizing conditions
Low pH
Negative charge
Strongly adsorbed

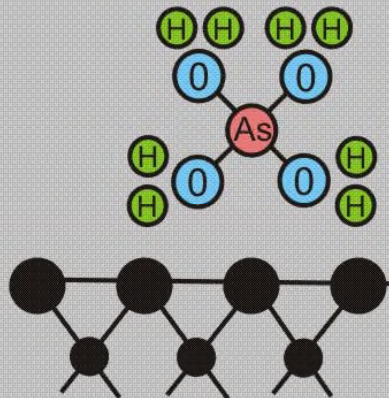


HAsO_4^{2-}
Oxidizing conditions
High pH
Negative charge
Strongly adsorbed

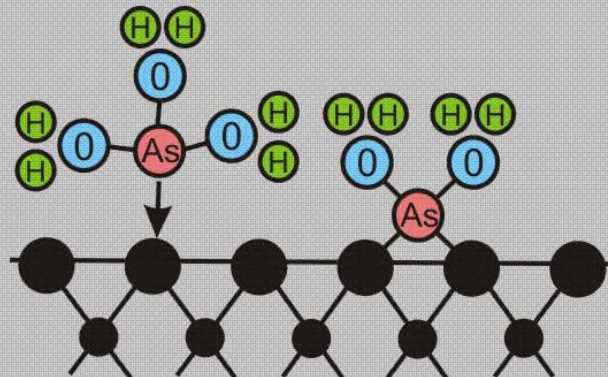
Arsenic on mineral surfaces

(modified from Brown, 1990)

Adsorption

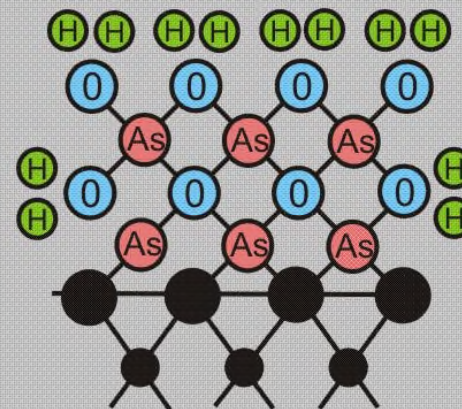


Outer-sphere
complex
(physisorbed)



Inner-sphere
complex
(chemisorbed)

Precipitation

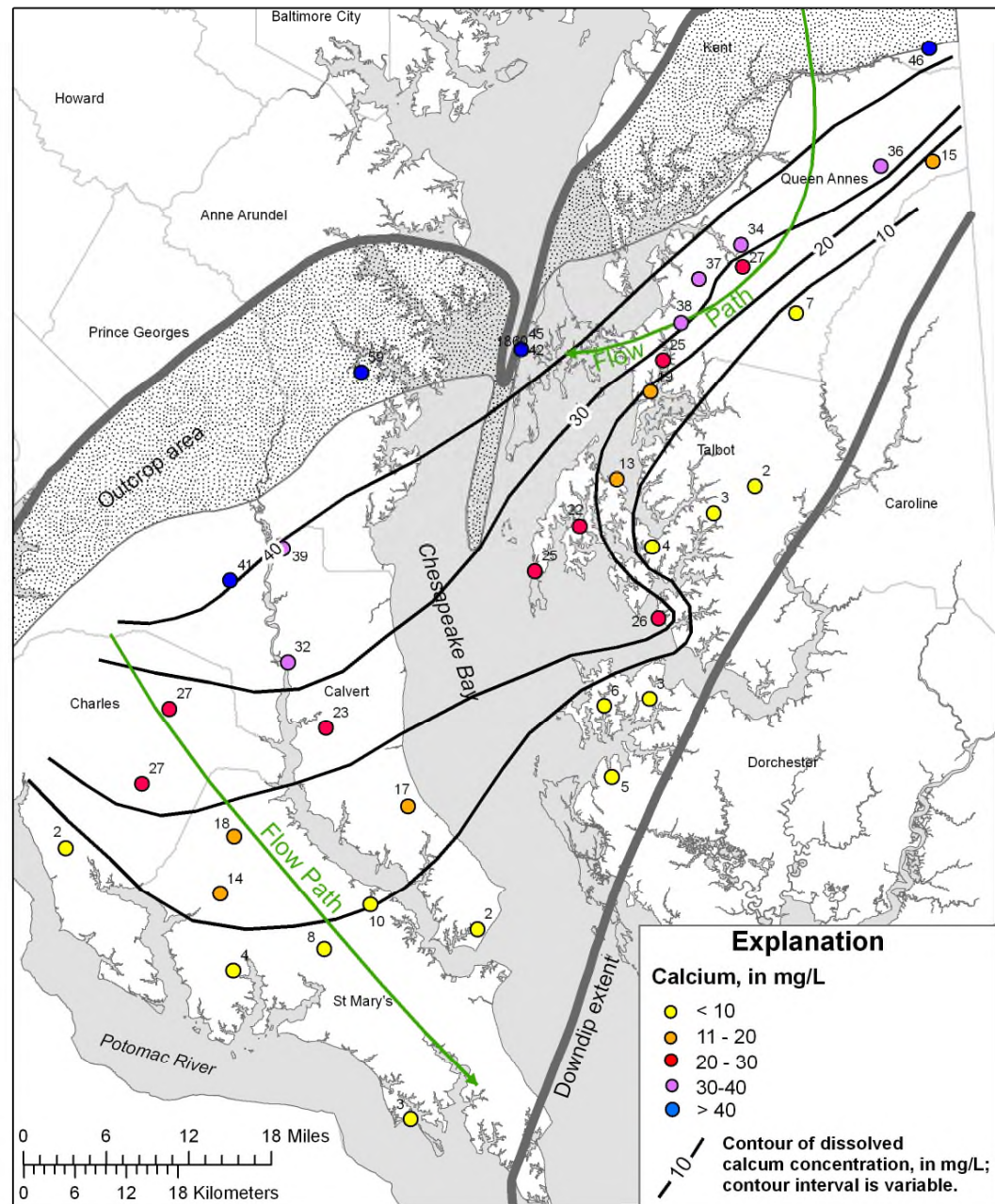


Surface Precipitation

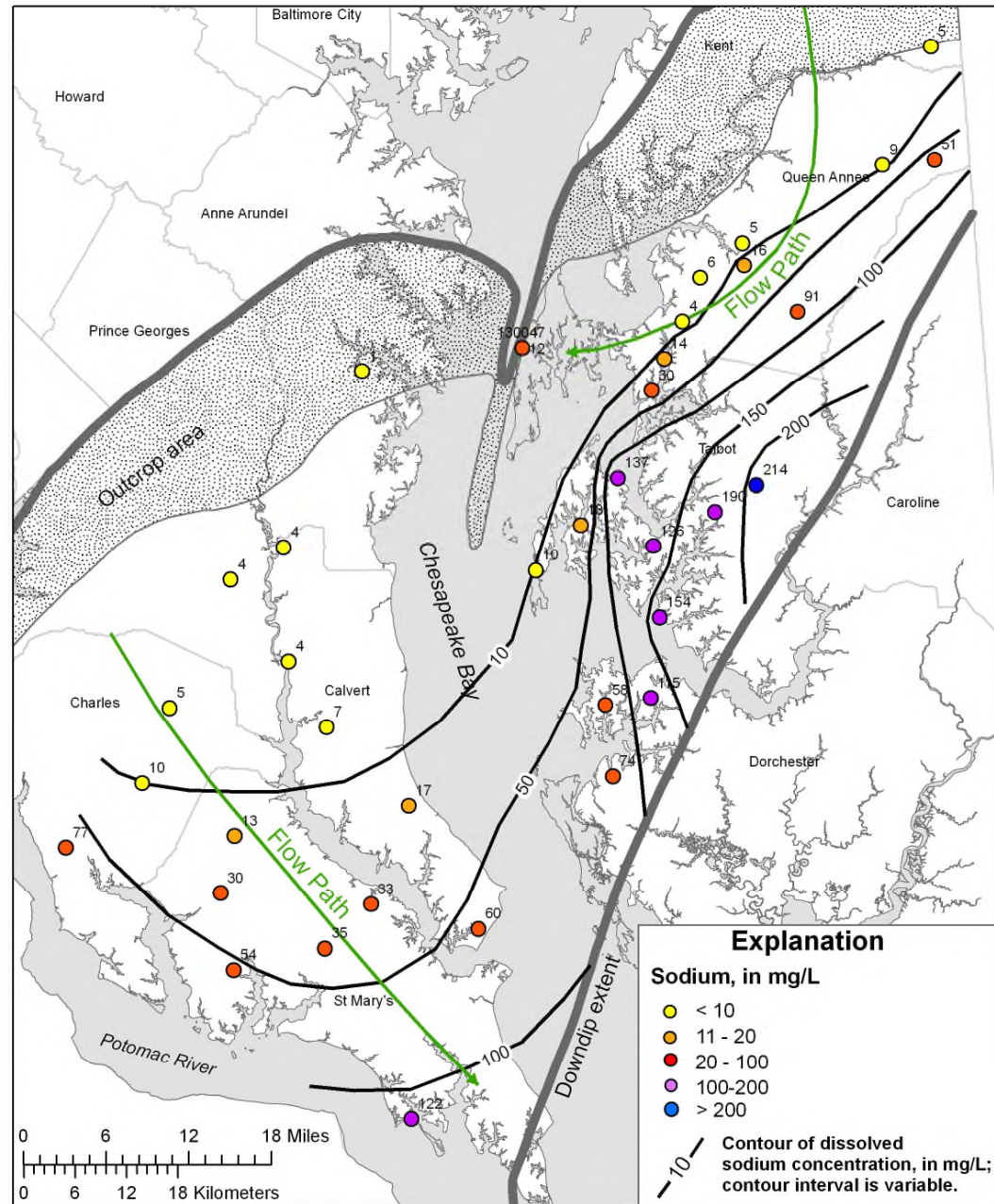
Arsenic trends

- Areas of elevated arsenic parallel trends in major-ion composition.
- Water chemistry evolves along pre-development flow path in Southern Maryland.
- Water chemistry does not seem to evolve along pre-development flow path on the Eastern Shore.

Calcium concentrations in the Aquia aquifer



Sodium concentrations in the Aquia aquifer



Possible sources of arsenic

- Recharge water (precipitation $<1 \mu\text{g/L}$)
 - Requires concentration mechanism
- Iron oxyhydroxide coatings on minerals
 - Reductive dissolution
- Shell material
 - Arsenic substitutes for calcium
- Phosphate pellets
 - Arsenic substitutes for phosphorous
- Glaucanite
 - Ion exchange

Conclusions

- Arsenic concentrations exceed the MCL of 10 $\mu\text{g/L}$ in ground water from some areas of the Aquia and Piney Point aquifers.
- The source of dissolved arsenic is natural, and probably derives from minerals within the aquifers.
- The distribution of arsenic is controlled by complex chemical interactions between ground water and aquifer material:
 - Reductive dissolution of iron oxyhydroxides
 - Dissolution of calcite or phosphate
 - Ion exchange on glauconite